CHARACTERIZATION OF SOLAR CELLS IN CLIMATIC CONDITIONS OF WESTERN RAJASTHAN

(पश्चिमी राजस्थान की जलवायु दशाओं में सौर सेलों का निस्पण)

A Synopsis

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CHAPTER.1 Introduction

In recent years, increasing population and scarcity of electricity especially for domestic use has lead researchers to explore alternative ways to meet electricity needs in India. Solar energy is considered to have potential of meeting energy demands in the country. Sun is unlimited source of light energy. Solar energy is an attractive way of producing electrical energy directly from sunlight using the "*photovoltaic effect*" without producing pollution (clean energy development). Today many silicon solar cells technology is the leading industry in the world market of solar energy, with a variety of end applications. This rapidly growing markets calls for advanced technologies and devices of yielding a good performance at lower cost. An enormous study is done concerning solar cell fabrication and characterization technology so far. Now it is time to implement solar energy technology to the society.

Western Rajasthan is a *golden bird in for harnessing the solar energy* in country. This region is one of the fast growing area in solar energy. The state of Rajasthan is located in the western part of India, which faces severe water scarcity, poor rainfall. Rajasthan is the largest state of India (342239 Km^2), covering about 10.4% of the country's total area. In which 60% (208110 Km^2) land is desert of the total area of state. Rajasthan receives one of the highest amounts of solar radiation (6.0-7.0 kWh/ m^2) (Pandey et al. 2012) amongst the best in the world for over 300 - 325 days a year. There is an attractive prosperity is available to setup solar hub. The output Solar Electricity from these hubs can be connected to the grid to supply electricity throughout the country.

Determining the performance of a PV system not only depends on its basic characteristics but also on some external conditions like incident

sunlight intensity, shading, ambient temperature etc (unconditional parameters). These factors are unpredictable.

Solar radiation and ambient temperature are the key parameters for design, development, application and assessment of outdoor solar energy systems in photovoltaic conversion process. In Rajasthan, ambient temperature varies 8°C to 28°C (winter) and 25°C to 49°C (summer) and high dust pollution are responsible for the output solar power degradation.

The study of optimization of power output with respect to climatic conditions is quite significant for quality control and the performance assessment of the solar cell system in climatic condition of Western Rajasthan.

1.1 Theoretical Basis

The solar cell performance can be characterized by most known parameters Open Circuit voltage V_{oc}, Short circuit Current I_{sc}, Fill Factor (FF) and Efficiency (η). These performance parameters directly depend on some external conditions mentioned as above. These conditions are unpredictable because these vary time by time in day, weak, month, year as well as geographical location.

Light intensity dependent parameter

$$V_{oc} = nV_t \ln\left(\frac{I_{ph}}{I_s}\right) \quad \text{and} \quad I_{sc} = bH$$

Temperature dependent parameter

(Green et. al., 1982)

Where I_s is the saturation current, I_{ph} is the photo generated current, V_t is the thermal voltage, H is incident light intensity and b is a constant depending on

semiconductor junction properties. Both parameters directly depend on solar radiation intensity as well as ambient temperature.

CHAPTER 2 Review of literature

India has a huge potential for harnessing the renewable energy. Renewable energy is essential to achieve a clean and sustainable society (Bahrami and zadeh 2013). Renewable energy sources play good role in accomplishing the main objectives of CDM (Clean development mechanism). The total estimated potential of renewable energy in India is about 84,000 MW and the electricity generation through renewable energy sources has reached to 20.4%. In 2010 the energy generation through wind energy has reached to 12,009.48 MW. Solar PV and biomass power is more than 12 MW and 901 MW respectively. Understanding the potential of solar energy, some researchers have assessed the potential of solar energy as an essential future energy source in the oil-rich United Arab Emirates (Mokri et al. 2013). Few other research groups have identified the solar hot spots in India using high resolution satellite data (Ramachandra 2011). It is mostly observed that nearly 58% of the country receives annual average global insolation of 5kWh/m^2/day which could help meet the country's escalating power requirements in a decentralized, efficient and sustainable manner (Ramachandra 2011).

The uses of non-renewable energy resources have severe adverse impacts on the environment. These potential burdens to the environment, which include during the construction, the installation and the demolition phases, as well as especially in the case of the central solar technologies noise and visual intrusion, green house gas emissions, water and soil pollution, energy consumption, labor accidents, impact on archaeological sites or on sensitive ecosystems, negative and positive socio-economic effects have been studied well (Tsoutsos 2005).

The use of solar energy in north-east Indian region is well studied by Baruah et al. for direct incident solar radiation, global horizontal solar

radiation and diffuse radiation incidence at different places (Baruah et al. 2012). The importance of tilt angle is well known for the thermal performance of evacuated tube solar air collector with reflector (Dabra et al. 2013). A solar model has been devised to establish a relation of efficiency of photovoltaic modules with the major climatic parameters like temperature and wind velocity for climatic conditions of Lucknow, INDIA (Siddiqui and Bajpai 2012). A relationship of efficiency of photovoltaic modules with the major climatic parameters like temperature, wind velocity; has shown good correlation with the measured data (Siddiqui and Bajpai 2012).

Since solar panels are generally installed in outdoor environmental conditions. The outdoor performance and degradation studies of PV systems by installation at different geographical locations and climatic zones could identify the stresses such as temperature, humidity, UV light exposure, moisture, thermal cycling etc. causing degradation, and could reliably correlate between the controlled laboratory conditions to harsh outdoor conditions to developed equate qualification standards (Sharma and Chandel 2013). The light intensity and temperature dependency of performance parameters of PV modules have been experimentally investigated by few research groups (Cucea et al. 2013). Ugwuoke and Okeke studied the characterization and performance evaluation of the PV modules under the influence of global and diffuse irradiance, and found the maximum power output and efficiencies of the modules were significantly lower than their rated performances. It was found that at the irradiance of 1000 W/m^2, the power output was reduced by about 31.88%, 42.32% and 30.6% of the manufacturer's specifications for the monocrystalline, polycrystalline and amorphous silicon PV modules respectively. Maximum efficiencies of 12.97%, 9.67% and 4.94% were achieved at irradiance of 600W/m2 for the monocrystalline, polycrystalline and amorphous silicon modules respectively

(Ugwuoke and Okeke 2012). Similarly, Mohammed and Rahman studied the efficiency of poly-crystalline, mono-crystalline and amorphous silicon solar module by applying single-axis time/date solar tracker to the installation of photovoltaic panel (dynamic system) as a strategy to increase the performance of the modules under hot-humid climate of Malaysia (Mohammed and Rahman 2012).

Nnadi investigated the climatic effects and environmental variations on the performance of a stand-alone photovoltaic system. They also investigated the effects of partial shading with different climate conditions and load resistance variations were examined (Nnadi 2012). Nguyen et al. investigated a neural network-based shadowing function to predict maximum possible output power of a solar PV array similar to experiencing non-uniform partial shading (Nguyen et al. 2009). Zulu and Kashweka investigated the influence of artificial light and shading on solar panel cells. They firstly exposed the panel cells to artificial light of three different power levels. Secondly, the panel cells were shaded by one-quarter, half and three-quarters. Current-voltage and power-voltage characteristics were determined for all cases (Zulu and Kashweka 2013). Sanusi et al. studied the effect of ambient temperature on the performance of an amorphous silicon photovoltaic system (ASPS) in a tropical area of Ogbomoso, Nigeria. Their research was carried out by monitoring the variation in power output of the system with ambient temperature of the area for three years, 2006, 2007, and 2008 (Sanusi et al. 2011). Wind intensity plays a key role and control of other environmental parameters explains the cell behavior in real operating conditions as well (Cornaro et al. 2008). A detailed experimental-based investigation for the impact of air pollution on PVs' performance for five months deposition on the panels' surfaces has been examined by few researchers (Khadim et al. 2012).

The impact of dust accumulation, humidity level and the air velocity on solar cell performance has been well studied (Mekhilef et al. 2012). Mani and Pillai reviewed the challenge involved with dust accumulation (Mani and Pillai 2010). Mohamed and Hasan studied the southern area of Libya through the period from (February to May) to seasonal winds, which usually carrying dust and sand. The deposition of tiny particles of sand, trees debris, and birds' droppings are accumulating on surface of PV modules, which yielded a shading sunlight on modules, with the consequence a significant power loss (Mohamed and Hasan 2012).

Kaldellis and Kokala studied the actual performance of five identical pairs of roof-top PV-panels, operating in the aggravated urban environment of Athens (from the atmospheric air pollution point of view). They took series of systematic experimental measurements within a certain time period and the influence of different dust deposition densities on the energy yield and the economic performance of the small power station was estimated (Kaldellis and Kokala 2010). Andrew et al. discussed on a methodology to derive snowfall losses and time to clear of snow from a time series of module performance data, an important metric commonly collected at PV installation sites (Andrew et al. 2013).

Mehrotra et al. presented electrical performance of the solar photovoltaic using water immersion cooling technique. This preliminary study of applying this technology in a university building of MANIT, Bhopal has been described with different water depths in the outdoor environment during a period of 6 days from 18/04/2014 to 23/04/2014 (Mehrotra et al. 2014).

Kandilli and Ulgen conducted studies on the transmission of concentrated solar energy via optical fibres (Kandilli and Ulgen 2009).

CHAPTER 3 Research gap

Solar energy is ultra clean, natural and a sustainable source of energy with massive financial and environmental benefits. The state government has also established Rajasthan Renewable Energy Corporation Limited (RRECL) a state nodal agency, which is committed to development and promotion of clean power in Rajasthan has launched an initiative to develop numerous solar sectors in the country. Rajasthan is blessed with two critical resources that are essential in solar power production: (1). High level of solar radiation, and (2). Large area of contiguous, relatively flat, waste land. Rajasthan is uniquely placed in India to tap solar radiations with 300-330 clear sunny days and average daily solar incidence of 5-7kWh/m^2. Barmer, Bikaner, Jaisalmer and Jodhpur are the key western regions with best solar radiation in the State.

Recent studies conducted with solar photo-voltaic (PV) cells include means to increase solar performance parameters in PV cells. Solar radiation and ambient temperature, shading are the key parameters for design, development, application and assessment of outdoor solar energy systems in photovoltaic conversion process. In Rajasthan, ambient temperature varies 8°C to 28°C (winter) and 25°C to 49°C (summer) and high dust pollution are responsible for the output solar power degradation.

The study of optimization of power output with respect to climatic conditions is quite significant for quality control and the performance assessment of the solar cell system in climatic condition of Western Rajasthan. There exists a research gap in assessment of solar performance parameters in climatic conditions of western Rajasthan. The state of Rajasthan, although blessed with high radiation but also has major drawbacks

i.e., high temperature and dust pollution. Since dust and high temperature are known to decrease solar performance.

The overarching goals of the proposed research include 1) Determining solar performance parameters in western Rajasthan climatic conditions and 2) Assess prospects of using optical fiber cable (OFC) to transmit light in enclosed volume spaces and its effects on solar performance parameters. An optical fiber cable is a best tool for carrying light signals over from outside to inside by total internal reflection. This study will lead to better understanding the potential of OFC in improving solar power performance parameters by protecting PV cells from dust, high ambient temperature and their security.

CHAPTER 4 Objective of study and work plan

The amount of solar energy reaching the Earth's atmosphere and surface is dependent on geographic location (latitude and longitude of the place), orientation, seasonal variations, time of a day, and atmospheric conditions. Study about the collection of solar energy is needed in many applications dealing with the harnessing of solar energy.

The main objectives of this research work are to analyze the effect of outdoor condition parameters like sun intensity, ambient temperature, dirt, dust pollution and bird dropping on solar cell performance in climatic condition of western Rajasthan. These factors are responsible for the fast degradation of solar PV systems, which could in turn down the PV performance.

Research work in this area would be revolutionary in harnessing the solar panels in different types of conditions at various places in climatic condition of western Rajasthan, since western Rajasthan is predicted as future solar energy hub which could meet the major energy demands of the country.
In real operating conditions, solar cells or panel are to be harnessed in directly contact with the outdoor climate conditions. This study shows how the optimization of solar power performance under outdoor climatic conditions can be achieved.

Specific Aim 1. To study effects of climatic conditions of western Rajasthan on solar performance parameters such as open circuit voltage V_{oc}, short-circuit current I_{sc} etc. in Photovoltaic (PV system) solar cells.

Hypothesis 1. Climatic conditions of western Rajasthan such as high ambient temperature and dust pollution negatively influence (Power degradation) the solar performance parameters.

Specific Aim 2. To study the effects of solar performance parameters such as open circuit voltage V_{oc}, short-circuit current I_{sc} etc. in solar cells when light is transmitted using optical fiber cable (OFC) in climatic conditions of Rajasthan.

Hypothesis 2. The use of OFC will improve solar performance parameters in western Rajasthan.

3.1 Work Plan:

Research work will be carried out under following objectives:

1. *Analysis of the effect of solar irradiance and ambient Temperature Open-Circuit Voltage and Short Circuit current in Rajasthan Climatic Conditions*.

This chapter covers the analysis of the effect of solar radiation power and ambient temperature on solar cell's performance parameters open circuit voltage V_{oc} and Open Circuit Current I_{sc} for different days of month at particular location in Jodhpur region (Rajasthan), India.

It is essential required to study of solar cell performance parameter under the different climatic condition at different places before harnessing of solar energy. The usefulness of such type of study is that we can estimate the solar cell performance at that situation.

2. *Study the effect of ambient temperature on solar cell performance.*

This chapter is very important in view of solar cell performance study. Ambient temperature is directly responsible for solar cell performance. In real situation solar cells or solar panels are directly touch with ambient temperature (outdoor condition parameter). In day, performance parameters are directly influenced with the fluctuations of ambient temperature. This

chapter discusses the study of the effect of temperature on performance under the conditional and unconditional situations and their trends.

3. *The Clearness Index Model for Estimation of Global Solar Radiation in Rajasthan/INDIA.*

Clearness index parameter provide the information concerning about the real solar radiation compared with the available solar radiation. Clearness index measures the attenuation of the solar radiation due to clouds and earth atmosphere and it also depends on the geographical location for which it is calculated. The clearness index, k_t is defined as the ratio of the global radiation received on a horizontal surface H_g to the extraterrestrial global solar irradiation H_0.

4. *Study the effect of dust shadow on solar cell performance.*

In this chapter we would study about the effect of shadow causing various small and large unusual objects (dust particles, birds & surrounding objects). Also study the fluctuating shadow with respect to time.

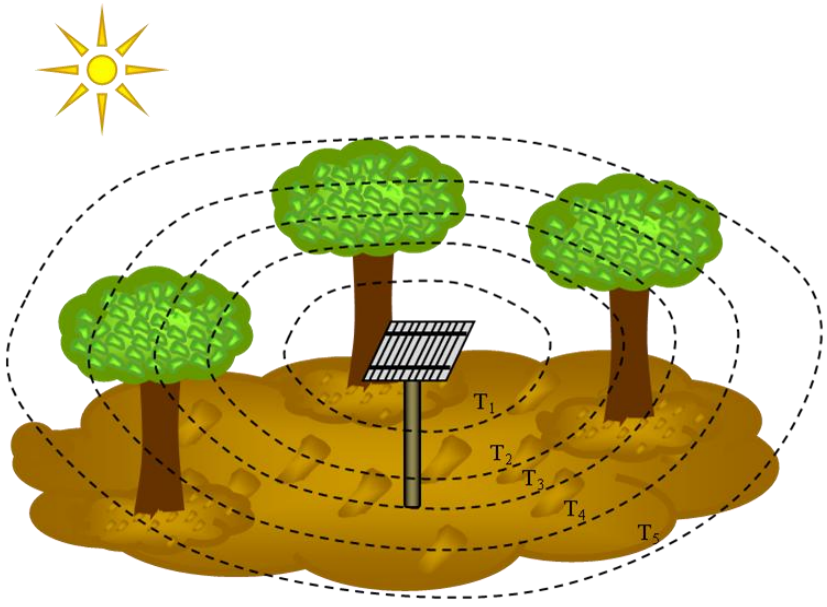

Fig.1. Study the effect of ambient temperature on PV systems surrounded by tress.

The importance of study is to overcome the effect of ambient temperature on the PV systems by the implementation of trees surrounded on it.

Fig 2. A bird sitting on solar plate

5. *Study the performance of Solar Module under composite parameter as Open Circuit voltage, Ambient Temperature and Sun power Intensity.*

Open circuit voltage and short circuit current are dependent variables and Ambient Temperature and Sun power Intensity are independent variables. Solar cell performance generally varies with respect to ambient temperature, wind velocity and sun radiation. The aim of this study is here to find out the variation of solar cell performance with ambient temperature, sun radiation humidity, wind velocity, humidity and bird dropping as composite parameters.

6. *Study the effect of unconditional parameters on solar cell performance using 'optical fiber cable' solution of the effect of temperature.*

In this chapter a new concept is introduced to seeking the solution of degradation of solar cell performance parameter by causing ambient temperature and dust particle accumulation as well. In summer the temperature of Rajasthan is very high (0-50°C) in outdoor climatic condition and room temperature is near about 35°C (*i.e., large difference between inside*

and outside temperature). We can improve the solar cell performance inside the room. But it is question mark that how is that possible? A new idea has generated to resolve this problem. We did use the optical fiber cable as light carrying bus tool inside the room. Another great advantage of this concept is that the dust pollution can also be reduced.

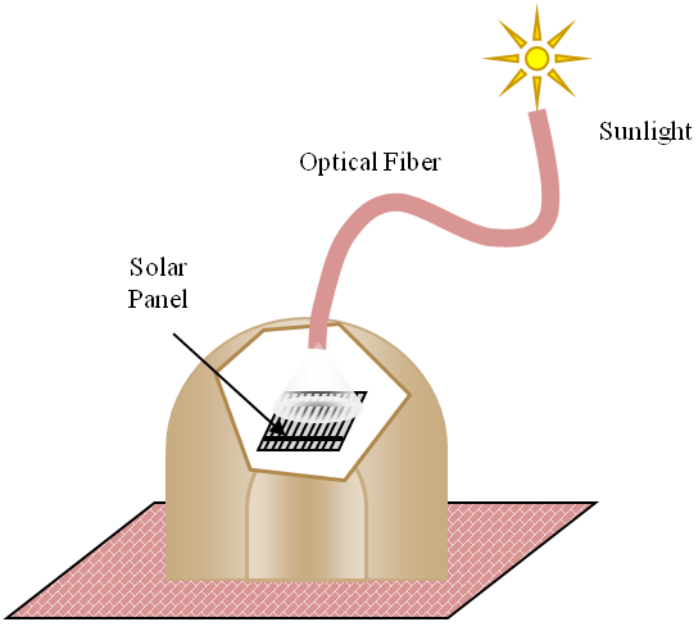

Fig.3. Carrying of sunlight by optical fiber cable inside the room.

Fig.4. Demonstration of light carrying through the OFC

An optical fiber cable is essentially a cylindrical waveguide and used to transmit light signals over long distances by total internal reflection.

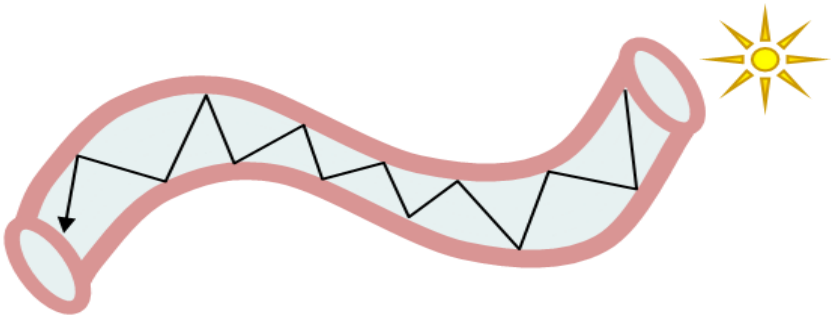

Fig.5. Total internal reflection of light

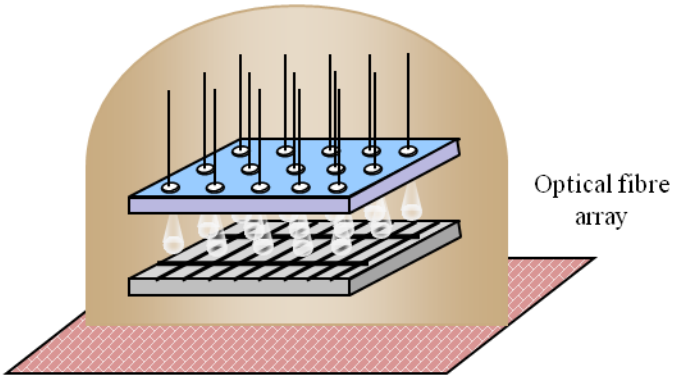

Fig.6. Optical Fiber Array (Bundle)

To improve the solar cell performance a new model is introduced that consisting with a bundle of optical fiber cable which is arranged in periodical array that can help in reducing the effect of dust deposition and temperature.

CHAPTER 5 Methodology & instrumental details

The purpose of this experiment study is to investigate the effect of ambient temperature and sun intensity on open circuit voltage V_{oc} and short circuit Current I_{sc} in outdoor conditions at the particular location. Solar cell (4 volt, -2 Watt) Omega Electronics Jaipur, India has been studied. The solar module has been connected to the digital multimeter (M830BZ) to record the V_{oc} and I_{sc}. Surya Mapi (SM 201A) Central Electronics LTD, India is used to measure sun intensity and Ambient temperature has been measured with the mercury glass thermometer (Jennson Deluxe).

Fig.7. Experimental arrangement for the assessment of the open circuit voltage and short circuit current.

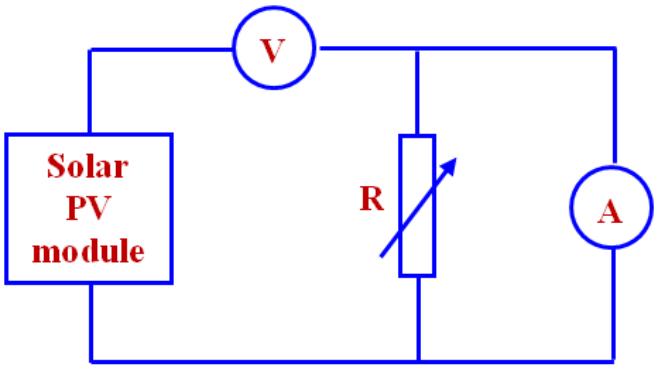

Figure.8. Circuit Diagram of the Experimental Set – up

Suryamapi, digital multimeter, and digital thermometer and solar cell is mounted on the tripod to study the effect of ambient temperature, sun intensity and dust particle on the solar cell performance.

(a) Suryamapi. measure sun light intensity since sunrise to sunset.

(b) Digital multimeter. Measure the output electrical characteristics (open circuit voltage and short circuit current) of solar cell.

(c) Digital thermometer. Measure the ambient temperature.

(d) Tripod. stable platform for keeping a solar cell on it.

(e) Watt Meter and Solar PV module analyzer. Measure output voltage and current from the solar cell's output that are essential to solar PV system performance (see fig.8.).

Fig.9. Wattmeter connected with the solar cell

(f) Glass plate (coupon). Study the effect of dust particle accumulation at the different places and locations of state (see Fig.9.).

Fig.10. Glass Plate

(g) Thermostat. A handmade design evacuated plastic box is used as thermostat to avoiding thermal losses by its surrounded in the assessment the effect of temperature (cooling and heating) on open circuit voltage and short circuit current (see fig.8.).

Fig.11. Thermostat

(h) Sunshine Hour Recorder

Sunshine recorder used as an instrument to measure the sunshine duration. Sunshine duration is the length of time that the ground surface is irradiated by direct solar radiation (i.e., sunlight reaching the earth's surface directly from the sun). A Campbell-Stokes sunshine recorder concentrates sunlight through a glass sphere onto a recording card placed at its focal point.

By courtesy: www.electronicsinstrumentsmanufacturer.com

Fig.12. Sunshine hour recorder

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